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ESTIMATING THE PROBABILITY OF NON-DETECTION OF LOW DENSITY POPULATIONS

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ABSTRACT: A method for estimating the probability of presence or absence of cryptic species was developed using the binomial distribution. For a given probability of detection (p) at a known population density during a unit effort of searching, the probability of non-detection during a specified number of search efforts can be estimated.

INTRODUCTION

Confirming the presence of elusive, secretive, or rare species in a large geographic area can be a frustrating task. Providing proof that the species is absent from an area may be impossible, but some form of an opinion statement concerning the presence of a population is often required as part of environmental assessments or for use in developing resource management schemes. When the species in question is an endangered one, the confirmation of its presence or absence may be required by law. If such a statement is based on rigorous, scientific study, with stated probabilities of error, it is more likely to be viewed as a reliable estimate rather than a subjective opinion.

This paper presents a conceptual framework for estimating the probability of presence or absence of species that are, by their very nature, difficult to observe. We will develop estimates of probabilities of non-detection. That is, given a specified density of the desired population, what would be the probability of no sightings for a specified level of searching?

Method

The probability of non-detection for a species at a specified population density can be estimated for any degree of searching, if the probability of finding a conclusive sign of the species during a single search effort is known for the species in question at the suspected density in the habitat being searched. If a search effort can be standardized, i.e., one unit of search effort equals searching for tracks along one mile of sandy road after a rain, or listening for vocalizations during the first hour after sunrise, etc., then the expected number of successful searches, x, for an effort of n searches can be described by the binomial distribution.

When this distribution is used, two assumptions must be met. The probability of detecting conclusive sign during one unit of search effort must be constant for all search efforts, and the probability of success during any one search effort must be independent of the success of other efforts. Given these assumptions, the distribution is characterized as:

$$f(x) = \frac{n!}{x!(n-x)!} p^x q^{n-x}, \qquad x = 0, 1, 2 \ldots n \tag{1}$$

where $f(x)$ = probability of x successful searches efforts during n attempts
p = the probability of success for any one search effort, and
$q = 1 - p$.

Estimates of p are dependent on the abundance, distribution, persistence, and distinctiveness of the conclusive signs, and the ability of the observer to notice them. Each of these factors is influenced by habitat, season, weather, human disturbance, and the sex and age structure of the population, as well as population density. Hence, estimates of p cannot be determined for a species in general, but must be made for each specific species-environment to be studied.

Data on resightings of marked white-tailed deer (*Odocoileus virginianus*) fawns were used to examine the feasibility of the binomial distribution model. The study area was an 826-ha enclosure on the Radford Army Ammunition Plant, Dublin, Virginia. A 2.4-m high cyclone fence topped with barbed wire formed the enclosure. The habitat was rolling grassland with small isolated stands of mature hardwoods and scattered red cedars (*Juniperus virginianus*). Approximately 80 ha of the enclosure have been planted with shortleaf pine (*Pinus echinata*), but few deer use these stands for cover. The area is traversed by an extensive road system that affords excellent observation opportunities throughout the entire enclosure.

Fawns were captured, marked with a unique set of colored ear streamers, and released during the Spring of 1969 as reported by Downing and McGinnes

(1969). A 30-km route was driven twice daily and sightings were recorded for each of the individually marked fawns. Searches were discontinued after three weeks, at which time the fawns were old enough to begin travelling with their mothers, and lost much of their cryptic nature. Detection of conclusive sign was defined as sighting a fawn during the 30-km drive. The 30-km route was the search effort unit. Seventy-three of the 81 fawns were known through later observations to have survived the three-week observation period, and those served as our search subjects. The search route was traversed 24 times during the observation period. Because deer were individually tagged, we had the equivalent of 1,752 search efforts for individual deer. A total of 73 sightings occurred during the search. Thus, the probability of sighting an individual fawn was:

$$p = \frac{73 \text{ sightings}}{1{,}752 \text{ efforts}} = 0.0417$$

Results

By substituting $p = 0.417$ and $n = 24$ into equation 1, we calculated the expected distribution of sighting frequencies (E_f) for an individual fawn. Our observed frequencies were not statistically different from expectations given a binomial distribution (Table 1). The probability of not detecting a specific fawn during n search efforts is calculated as:

$$f(x = 0) = q^n \tag{2}$$

For $p = 0.0417$ and $n = 24$, $f(x = 0) = (1 - 0.0417)^{24} = 0.36$. The number of search efforts required for a specified $f(x = 0)$ is calculated as:

$$n_0 = \frac{\ln[f(x = 0)]}{\ln q} \tag{3}$$

For $f(x = 0) = 0.05$:

$$n_0 = \frac{-2.9957}{\ln q} \tag{4}$$

For $p = 0.0417$ and $f(x = 0) = 0.05$, $n = 71$. Searching for fawns with an assumed density of 1/826 ha and $p = 0.0417$ would require 71 unsuccessful search efforts before there was less than a 5% chance of error in concluding that the animal was truly absent.

The relationship between the number of required search efforts and specified levels of $f(x = 0)$ can be calculated for an array of p values (Fig. 1).

TABLE 1.—Observed and expected frequencies assuming a binomial distribution of sightings of individual marked fawns during 24 search efforts on the Radford Army Ammunition Plant, Dublin, Virginia (1969).

No. of sightings after capture (x)	Observed frequency (O_f)	Expected frequency (E_f)	
0	26	26.3	$X^2 = \sum_{x=0}^{\geq 3} \frac{(O_f - E_f)^2}{E_f}$
1	29	26.3	
2	9	13.7	$= 3.85^a$
≧3	9	5.7	

[a] Not significant at $\alpha = 0.05$, 3 d.f. Frequencies for 3, 4, 5 and 6 sightings were combined so that O_f and $E_f \geq 5$.

DISCUSSION

Anyone planning to search for cryptic animals should attempt to determine the probability of observing conlusive sign, so that searches can be designed to have a statistically significant result. Nothing can be concluded after 10 days of unsuccessfully searching an area, for example, if 20 days are required to state with 95% confidence that the animal being sought is not there. In fact, an insufficient effort may do more harm than good, because persons who are not familiar with statistical probabilities may conclude that the animal is not present after 10 unsuccessful search attempts, when such a conclusion may have a high probability of error. In order to obtain credible appraisals of presence or absence of cryptic species, the probability of detection should be known. Rigorous, scientific, quantified search efforts reported with their associated probabilities of error are far more desirable than popular sentiment and hearsay evidence. In situations where estimates of detection probabilities are costly or difficult to obtain, a range of likely detection probabilities can be used to judge the adequacy of searching effort.

The cougar study reported by Downing (1984) is a case in point. Downing recognized the need to measure the probability of observing cougar sign before beginning a systematic search of the Appalachian Mountains, in the southeastern United States. However, he also recognized that cougar tracks are indistinct in these mountains, due to the hard soil conditions. Measures of the probability of observing cougar sign are possible to obtain in Florida, the western United States, and South America; but these might not be applicable to Appalachian conditions. Reports of cougar sightings were so frequent that he enlisted the aid, through publicity and training, of hundreds of cooperators to find signs of a few cougars. These cougars could be intensively studied to estimate the probability of observing sign. Unfortunately, no cougars were found in the three years allocated to this broad-brush approach, and funds were not available to go to a comparable area known to contain cougars. Another possibility would have been to record the frequency

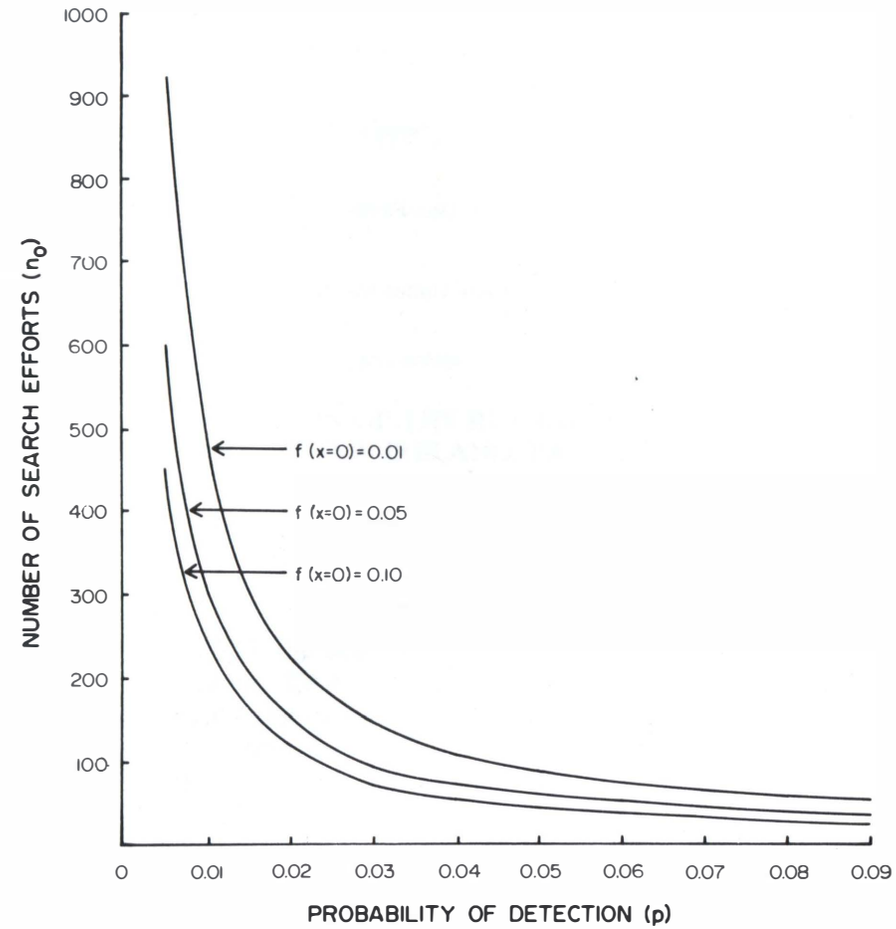

FIG. 1.—Number of search efforts (n_0) required at $f(x = 0) = 0.01, 0.05, 0.10$ at values of $0.005 \leq p \leq 0.09$.

of observing the tracks of bobcats (*Lynx rufus*), the nearest local relative of the cougar, and make some appropriate behavioral adjustments. Such adjustments would have included consideration of how far each species travels each night, and differences in where they travel that might affect track observability. Before Downing could determine the probability of observing sign, and hence attach some estimate of reliability to his findings, the project was closed because of the lack of evidence from the three-year broad-brush study.

We recommend using a range of p values which will likely encompass the "true" value of p for the specific population-environment-technique situa-

tion, and then calculate f(x) for a single sighting (or some other number of sightings) across a range of n values. This matrix of f(x) values can serve as an information base for planning and feasibility studies.

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